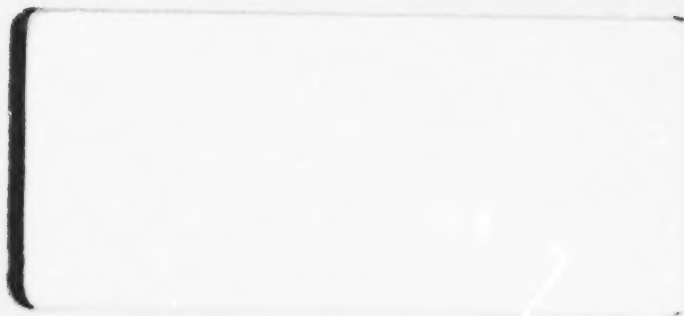




**Manitoba
Environment
and Workplace
Safety and Health**



Phase II Survey of Ambient Air Levels
of PAH in Winnipeg

by Special Studies Program
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Abstract

A second phase study was undertaken to determine if polynuclear aromatic hydrocarbons (PAH) are present in the ambient air of Winnipeg. Sampling was performed at 4 urban Winnipeg sites using high-volume (hi-vol.) particulate samplers equipped with teflon filters. An adaptation of the method was attempted and assessed to try to obtain total suspended particulate (TSP) measurements from the same filter. Samples were obtained over 24-hour periods every 3rd day during a 13 week period from January 4 to March 29, 1985.

Quantification of PAH was possible at low levels with 21 out of 582 (4%) results positive. All positive results were less than detection limits in a previous study (where only one positive was found) and therefore it would seem that ambient levels are probably at or very near background concentrations.

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1. INTRODUCTION

Due to the continuing widespread use of wood combustion as a source of, or supplement to, residential heating, studies have been undertaken to investigate if this phenomenon was having an effect on urban air quality. A second round of monitoring for polynuclear aromatic hydrocarbons (PAH) was undertaken during the winter of 1984-85. This was a follow-up to monitoring performed in the winter of 1983-84.¹ This phase II monitoring (sampling) was similar in method to the preliminary survey and was conducted at 4 urban Winnipeg sites. Two of the sites were previously used and 2 new ones were established. Complete descriptions are given in the Monitoring Sites section. Sampling frequency was increased over the first survey with samples obtained approximately every third day, commencing January 4 and finishing March 29, for a total of 25 scheduled sampling days.

The report from the previous project gives an outline on the generation and characterization of PAH.¹ Recent literature on the subject has indicated that the total number of characterized PAH compounds is now in excess of 250 different chemical species.² The specific PAH compounds in this study were the same as in the preliminary study:

- 1) Fluorene $C_{13}H_{10}$ Molecular Weight = 166.2
- 2) Fluoranthene $C_{16}H_{10}$ M.W. = 202.3
- 3) Benzo[a]pyrene $C_{20}H_{12}$ M.W. = 252.3 (also called 3,4-Benzopyrene)
- 4) Phenanthrene $C_{14}H_{10}$ M.W. = 178.2

- 5) Chrysene $C_{18}H_{12}$ M.W. = 228.3 (also called 1,2-Benzophenanthrene) and Triphenylene $C_{18}H_{12}$ M.W. = 228.3 (also called 9,10-Benzophenanthrene)
- 6) Pyrene $C_{16}H_{10}$ M.W. = 202.1

Despite the lack of positive results from the first survey, the assumption remained that wood burning was a major source of PAH in Winnipeg and that emissions would be greatest throughout the winter months.

The objectives of this study were:

- 1) To determine (using high-volume particulate sampling) if detectable quantities of polynuclear aromatic hydrocarbons were routinely present in urban ambient air.
- 2) To render an assessment of PAH impact on air quality, if they are present, by comparing levels with those found in other jurisdictions and last year's results.
- 3) To try to identify and quantify spatial differences in concentrations from different areas of the city and if possible provide some insight into possible factors contributing to this.
- 4) To assess the equilibration techniques used to prepare PAH filters for gravimetric total suspended particulate (TSP) analysis prior to extraction in the laboratory.

2. PROCEDURES

Sampling was conducted using standard high-volume particulate samplers with Pallflex Emfab teflon filters. This sampling methodology was consistent with the Environment Canada reference method, "Standard Reference Method for the Measurement of Suspended Particulate in the Atmosphere (High Volume Method)," EPS Report No. 1-AP-73-2 (January 1983). Sampling periods were of 24 hours duration.

For this project special handling procedures were involved and this permitted gravimetric TSP analysis. The special handling consisted of refrigeration of exposed filters during a desiccation period, (equilibration). The assumption is that the volatilization of organics on the filter will be minimized under cooled conditions.³ The equilibration period, which often lasted from 24-36 hours in duration, was also carried out in darkness in hopes that any potential photo-degradation of PAH compounds would also be minimized.⁴ Subsequent to gravimetric analysis the filters were promptly extracted for PAH analysis.

Entire filters were run through a Soxhlet extraction and aliquots of the extract were purified and then run on a gas chromatograph. The resultant spectra were compared to standard samples of the six compounds which were prepared and analysed on the same instrument. Elution time was the criterion of identification and peak height was indicative of concentration. It was in the extraction and purification process that significant improvements were made since

the first survey, last year. It was as a result of these improvements that there was a significant reduction in the detection limits for some of the PAH compounds.

2.1 Monitoring Sites

For this project four monitoring sites were employed and all were within urban Winnipeg. Two of these urban locations are part of the Federal Government's National Air Pollution Surveillance (NAPS) network, while the other two (new) sites were selected in residential locales. The two NAPS stations have the samplers situated above ground level at approximately 3-5 metres height. The other two residential samplers were placed right at ground level thus representing breathing zone concentrations.

- 1) NAPS Station 9118 - Located at 299 Scotia Street (West Kildonan), regarded as representative of an urban residential environment.
- 2) NAPS Station 9120 - Located at 604 St. Mary's Road (St. Vital - north), regarded as representative of an urban residential environment.
- 3) PAH Station #3 - Located at 62 Falconer Bay (St. Vital - south) regarded as representative of sub-urban residential environment.
- 4) PAH Station #4 - Located at 72 Woodchester Bay (Charleswood) regarded as representative of sub-urban residential environment.



3. RESULTS

For the period of monitoring, samples were collected at each of the four sites, approximately every third day for a total of 97 samples. Each filter (sample) was analyzed for 6 separate PAH compounds (chrysene and triphenylene constitute one test). There were 21 positive results out of the 582 analytical tests performed. A positive result is one which is at a level greater than the lower detection limit for the specific compound.

Tables 1 to 4 summarize the results of sampling at each station. For each station, a mean and range of air volumes is given. These volumes determine the lower detectable concentration limit.

Table 1 - Results of sampling at Station 9118

Date	Wind Direction	Wind Speed (Knots)	PAH concentrations (ng/m ³)*					Chrysene Triphenylene B[a]p	TSP (µg/m ³)**
			Fluorene	Phenanthrene	Fluoranthene	Pyrene			
85-01-04	W	8	<3.0	<3.0	<3.0	<3.0	<5.3	<25.9	16
85-01-10	NW	6	<2.7	<2.7	<2.7	<2.7	<4.9	<24.1	14
85-01-13	NW	16	<2.9	<2.9	<2.9	<2.9	<5.2	<25.6	24
85-01-16	SSW	4	<2.9	<2.9	<2.9	5.8	<5.2	<25.4	34
85-01-19	NW	14	<2.8	<2.8	<2.8	<2.8	<5.0	<24.4	17
85-01-22	W	8	<2.9	<2.9	<2.9	<2.9	<5.2	<25.5	14
85-01-25	NW	9	<2.8	<2.8	<2.8	3.0	<5.1	<24.8	17
85-01-31	W	6	<2.9	<2.9	<2.9	<2.9	<5.2	<25.3	16
85-02-03	W	7	<2.9	3.5	<2.9	4.2	<5.3	<25.9	27
85-02-06	SSE	14	<2.8	<2.8	<2.8	<2.8	<5.0	<24.7	19
85-02-09	ESE	9	<3.1	<3.1	<3.1	<3.1	<5.5	<26.8	37
85-02-12	SSE	8	<2.1	<2.1	2.2	3.2	<3.8	<18.6	24
85-02-15	SSE	10	<2.3	<2.3	2.5	2.8	<4.3	<21.1	19
85-02-21	NW	9	<2.6	<2.6	<2.6	<2.6	<4.6	<22.4	19
85-02-24	S	12	<2.6	<2.6	<2.6	<2.6	<4.7	<23.1	23
85-02-27	S	12	<2.5	<2.5	<2.5	<2.5	<4.6	<22.3	29
85-03-02	NW	10	<2.5	<2.5	<2.5	<2.5	<4.5	<21.9	28
85-03-05	S	6	<2.8	<2.8	<2.8	<2.8	<5.0	<24.4	130
85-03-08	NW	8	<2.5	<2.5	<2.5	<2.5	<4.6	<22.3	30
85-03-14	N	5	<2.5	<2.5	<2.5	<2.5	<4.5	<21.9	30
85-03-17	S	8	<2.7	<2.7	<2.7	<2.7	<4.9	<23.7	39
85-03-23	ESE	9	<2.6	<2.6	<2.6	<2.6	<4.7	<22.9	32
84-03-26	N	10	<2.7	<2.7	<2.7	<2.7	<4.8	<23.3	29
85-03-29	NNE	10	<2.5	<2.5	<2.5	<2.5	<4.5	<22.0	47

Air Volume Samples: Range 1640-2367m³ n=24
Mean 1870m³

* ng/m³ = nanograms (10⁻⁹ grams) per cubic metre. Values corrected to standard conditions of 25°C and 101.3 kilopascals of pressure.

** µg/m³ = micrograms (10⁻⁶ grams) per cubic metre.

Table 2 - Results of sampling at Station 9120

Date	Wind Direction	Wind Speed (Knots)	PAH concentrations (ng/m ³)*					Chrysene Triphenylene B[a]p	TSP (µg/m ³)**
			Fluorene	Phenanthrene	Fluoranthene	Pyrene			
85-01-04	W	8	<4.0	<4.0	<4.0	<4.0	<7.2	<35.4	18
85-01-10	NW	6	<3.6	<3.6	<3.6	<3.6	<6.5	<32.0	46
85-01-13	NNW	16	<4.6	<4.6	<4.6	<4.6	<8.3	<40.6	40
85-01-16	SSW	4	<3.9	<3.9	<3.9	<3.9	<7.1	<35.5	46
85-01-25	WNW	9	<3.7	<3.7	<3.7	<3.7	<6.7	<32.6	33
85-01-31	W	6	<4.5	<4.5	<4.5	<4.5	<8.0	<39.1	29
85-02-03	W	7	<3.4	<3.4	<3.4	4.8	<6.0	<29.5	35
85-02-06	SSE	14	<3.9	<3.9	4.9	5.3	<7.0	<34.0	52
85-02-09	ESE	9	<3.6	<3.6	<3.6	<3.6	<6.4	<31.5	25
85-02-12	SSE	8	<4.0	<4.0	<4.0	5.8	<7.2	<35.1	52
85-02-15	SSE	10	<3.7	<3.7	<3.7	<3.7	<6.7	<32.9	26
85-02-21	NW	9	<3.9	<3.9	<3.9	<3.9	<7.0	<34.4	45
85-02-24	S	12	<4.1	<4.1	<4.1	<4.1	<7.3	<35.9	33
85-02-27	S	12	<3.9	<3.9	<3.9	<3.9	<7.0	<34.3	23
85-03-02	NNW	10	<4.0	<4.0	<4.0	<4.0	<7.3	<35.6	100
85-03-05	S	6	<4.0	<4.0	<4.0	<4.0	<7.2	<35.0	85
85-03-08	WNW	8	<4.1	<4.1	<4.1	<4.1	<7.4	<36.3	44
85-03-14	N	5	<4.1	<4.1	<4.1	<4.1	<7.3	<35.7	92
85-03-17	S	8	<4.3	<4.3	<4.3	<4.3	<7.6	<37.4	67
85-03-20	SSE	14	<4.1	<4.1	<4.1	<4.1	<7.5	<36.5	115
85-03-23	ESE	9.4	<4.1	<4.1	<4.1	<4.1	<7.3	<35.7	71
85-03-26	N	10	<4.3	<4.3	<4.3	<4.3	<7.7	<37.8	52
85-03-29	NNE	10	<4.0	<4.0	<4.0	<4.0	<7.2	<35.1	162

Air Volume Samples: Range 1080-1492m³ n=23
Mean 1260m³

* ng/m³ = nanograms (10⁻⁹ grams) per cubic metre. Values corrected to standard conditions of 25°C and 101.3 kilopascals of pressure.

** µg/m³ = micrograms (10⁻⁶ grams) per cubic metre.

Table 3 - Results of sampling at PAH Station No.3

Date	Wind Direction	Wind Speed (Knots)	PAH concentrations (ng/m ³)*					Chrysene Triphenylene B[a]p	TSP (µg/m ³)**
			Fluorene	Phenanthrene	Fluoranthene	Pyrene			
85-01-04	W	8	<2.8	<2.8	<2.8	<2.8	<5.0	<24.5	18
85-01-10	NW	6	<2.5	<2.5	<2.5	<2.5	<4.4	<21.7	19
85-01-13	NW	16	<2.6	<2.6	<2.6	<2.6	<4.7	<23.1	19
85-01-16	SSW	4	<2.3	<2.3	<2.3	<2.3	<4.1	<20.2	14
85-01-19	NW	14	<2.2	<2.2	<2.2	<2.2	<4.0	<19.5	11
85-01-25	NW	9	<2.7	<2.7	<2.7	<2.7	<4.9	<23.9	18
85-01-31	W	6	<2.6	<2.6	<2.6	<2.6	<4.7	<23.1	16
85-02-03	W	7	<2.6	<2.6	<2.6	<2.6	<4.6	<22.5	26
85-02-06	SSE	14	<2.7	3.0	5.2	6.0	<4.9	<24.1	29
85-02-09	ESE	9	<2.7	<2.7	<2.7	<2.7	<4.9	<24.1	18
85-02-12	SSE	8	<2.8	<2.8	<2.8	<2.8	<5.0	<24.7	33
85-02-15	SSE	10	<2.8	<2.8	<2.8	<2.8	<5.1	<24.9	20
85-02-21	NW	9	7.9	<2.8	<2.8	<2.8	<5.1	<24.8	27
85-02-24	S	12	<3.0	<3.0	<3.0	<3.0	<5.4	<26.4	20
85-02-27	S	12	<3.0	<3.0	<3.0	<3.0	<5.3	<26.0	15
85-03-02	NW	10	2.9	<2.8	<2.8	<2.8	<5.1	<25.0	47
85-03-05	S	6	<2.9	<2.9	<2.9	<2.9	<5.3	<25.7	62
85-03-08	NW	8	<2.9	<2.9	<2.9	<2.9	<5.2	<25.5	22
85-03-14	N	5	<2.9	<2.9	<2.9	<2.9	<5.2	<25.5	51
85-03-17	S	8	<3.0	<3.0	<3.0	<3.0	<5.4	<26.5	29
85-03-20	SSE	14	<2.9	<2.9	<2.9	<2.9	<5.2	<25.6	31
85-03-23	ESE	9	<3.0	<3.0	<3.0	<3.0	<5.5	<26.8	32
85-03-26	N	10	<3.0	<3.0	<3.0	<3.0	<5.5	<26.7	33
85-03-29	NNE	10	<2.8	<2.8	<2.8	<2.8	<5.1	<24.9	78

Air Volume Samples: Range 1642-2255m³ n=25
Mean 1814m³

* ng/m³ = nanograms (10⁻⁹ grams) per cubic metre. Values corrected to standard conditions of 25°C and 101.3 kilopascals of pressure.

** µg/m³ = micrograms (10⁻⁶ grams) per cubic metre.

Table 4 - Results of sampling at PAH Station No.4

Date	Wind Direction	Wind Speed (Knots)	PAH concentrations (ng/m ³)*					Chrysene Triphenylene B[a]p	TSP (µg/m ³)**
			Fluorene	Phenanthrene	Fluoranthene	Pyrene			
85-01-04	W	8	<2.5	<2.5	<2.5	<2.5	<4.5	<22.1	12
85-01-10	NW	6	<2.3	<2.3	<2.3	<2.3	<4.2	<20.3	14
85-01-13	NW	16	<2.5	<2.5	<2.5	<2.5	<4.5	<22.1	26
85-01-16	SSW	4	<2.5	<2.5	<2.5	<2.5	<4.5	<22.2	28
85-01-19	NW	14	<2.4	<2.4	<2.4	<2.4	<4.2	<20.7	24
85-01-22	W	8	<2.5	<2.5	<2.5	<2.5	<4.5	<21.9	12
85-01-25	WNW	9	<2.4	<2.4	<2.4	<2.4	<4.3	<20.8	11
85-01-31	W	6	<2.4	<2.4	<2.4	2.5	<4.2	<20.7	13
85-02-03	W	7	<2.4	<2.4	<2.4	<2.4	<4.2	<20.7	19
85-02-06	SSE	14	<2.4	<2.4	<2.4	<2.4	<4.3	<20.9	19
85-02-09	ESE	19	<2.4	<2.4	<2.4	<2.4	<4.3	<20.9	26
85-02-12	SSE	8	<2.6	<2.6	2.8	4.6	<4.7	<22.8	35
85-02-15	SSE	10	<2.5	<2.5	<2.5	<2.5	<4.4	<21.5	16
85-02-21	NW	9	<2.5	<2.5	<2.5	<2.5	<4.5	<22.0	14
85-02-24	S	12	<2.6	<2.6	<2.6	<2.6	<4.7	<22.7	17
85-02-27	S	12	<2.5	<2.5	<2.5	<2.5	<4.5	<22.0	14
85-03-02	NW	10	3.1	<2.5	<2.5	<2.5	<4.5	<22.1	35
85-03-05	S	6	<2.5	<2.5	<2.5	<2.5	<4.5	<22.1	67
85-03-08	WNW	8	<2.5	<2.5	<2.5	<2.5	<4.5	<22.0	18
85-03-14	N	5	<2.5	<2.5	<2.5	<2.5	<4.5	<22.0	25
85-03-17	S	8	<2.7	<2.7	<2.7	<2.7	<4.8	<23.3	27
85-03-20	SSE	14	<2.6	<2.6	<2.6	<2.6	<4.6	<22.6	15
85-03-23	ESE	9	<2.7	<2.7	<2.7	<2.7	<4.7	<23.0	23
85-03-26	N	10	<2.7	<2.7	<2.7	<2.7	<4.8	<23.6	30
85-03-29	NNE	10	<2.5	<2.5	<2.5	<2.5	<4.5	<22.1	38

Air Volume Samples: Range 1866-2169m³ n=25
Mean 2015m³

* ng/m³ = nanograms (10⁻⁹ grams) per cubic metre. Values corrected to standard conditions of 25°C and 101.3 kilopascals of pressure.

** µg/m³ = micrograms (10⁻⁶ grams) per cubic metre.

Table 5 - TSP Concentration ($\mu\text{g}/\text{m}^3$) Comparison

Sampling Date	PAH Station 1		PAH Station 2	
	PAH (TSP)	NAPS (TSP)	PAH (TSP)	NAPS (TSP)
85-01-13	24.3	26.7	39.7	24.0
19	17.4	17.0		
25	16.6	14.4		
31	15.9	15.5	28.7	16.0
02-06	19.3	18.3	51.7	41.9
12	24.1	30.4	51.7	31.0
24	23.3	19.3	33.4	23.4
03-02	27.6	30.6	99.8	61.4
08	30.0	23.4	44.2	33.1
14			92.3	72.0
20			114.4	73.4
26	28.5	25.9	52.1	51.9

mean difference	0.6	18.0
st. deviation	3.7	12.9
Statistical "t" =	0.47	4.41*
α .05 =	2.26	2.26

If data is transformed in Common Log (TSP concentrations customarily display log - normal distributions.⁵)

mean difference	log 1.05 (0.02)	log 1.45 (0.16)
st. deviation	log 1.15 (0.06)	log 1.20 (0.08)
Statistical "t"	2.92*	3.82*
α .05 =	2.26	2.26

* these values indicate a significant difference in the results with 95% confidence limits.

4. DISCUSSION OF RESULTS

The minimum detectable mass, on each filter, for specific PAH compounds is constant independent of sampled air volumes. It was in this regard that some significant improvements were made since last year's project.

The minimum detectable mass ($\mu\text{g}/\text{filter}$) for each is:

	1985	1984
Fluorene	5.0	10.3
Phenanthrene	5.0	9.0
Fluoranthene	5.0	7.2
Pyrene	5.0	13.6
Chrysene and Triphenylene	9.0	9.4
Benzo[a]pyrene	44.0	44.1

In relation to concentrations in air, the detection limit (ng/m^3 - see Tables 1-4) is inversely proportional to the air volume sampled. As the total volume sampled increases the lower detectable concentration limit for each PAH becomes more sensitive. Thus, the greater the sampled volume of air the lower the minimum detectable concentration.

Similar to last year's study there were some trace results. These trace results were characterized by chromatographic peaks which because of their low magnitude cannot be regarded, with confidence, as positive results. These traces were further classified into 2 groupings. One group was where approximate quantification was possible and the other where there were minute peaks (blips) with not even approximate quantification possible. As with the tabulated

positive results elution time was the criterion of confirmation in these observations. Since these trace results were below the detection limit there is no justification for recording them. The only reason they are mentioned is because they seem to provide substantiation for some of the observations tendered with respect to the actual positive results.

While there are not enough positive results to undertake an appropriate statistical analysis to test certain correlations the data does permit some intuitive inferences. These inferences represent areas which could be investigated further in future studies.

- There were 9 days on which positive PAH results were obtained.

- At no time were positive results for Chrysene and Triphenylene or Benzo[a]pyrene obtained.

- All of the positive results (concentrations), for the other PAH's, obtained from monitoring in this study were less than the lower detection limits for the same compounds in the preliminary study.

- Days with positive PAH results were characterized by light or light to moderate winds. These conditions lead to reduced circulation of ambient air and thus poor dispersion, therefore, contributing to a potential build up of PAH levels.

- On 4 of the 9 days, positive results appeared at more than one station. On these days one or more PAH compounds were measured at two or more sites. There may be a relationship between wind direction and concentration as demonstrated by spatial variations in concentration on these days. It seems likely that there is an "urban plume" (increased background levels) in Winnipeg and that during

periods of intensified generation, winter, there may be a downwind potentiation of PAH levels.

The fact that the same PAH compounds are found at different sites on the same day suggests there may be a degree of commonality in the generation of PAH on these days. Conversely, the fact that different PAH's were found on different days at the same site suggests an aspect of variability. Both observations merit further investigation.

With regards to this variability, it was mentioned in the preliminary report that a review of pertinent literature indicated that the temperature of combustion is an important factor in determining which PAH compounds will be generated.¹ Temperature of combustion also has a very significant effect on the amount of a specific PAH produced.² This reference makes the observation that the profile of PAH's is about the same for different fuels at the same temperature. Therefore the PAH profile (profile is a more qualitative than quantitative term) seems to depend predominantly on temperature. The total amount of PAH produced at a given temperature can vary greatly for different fuels even if the profile is similar.

5. CONCLUSIONS

A comparison of TSP results between colocated samplers running concurrently at 2 stations on certain days (see Table No. 5) reveals that there appears to be a significant difference between the measured TSP levels. Since only very low concentrations of PAH, often less than detection limits, were found, it is likely the extra mass on the PAH filters was moisture and not PAH's which had volatilized from the NAPS filters. Thus it would seem that the desiccation process (equilibration) was not complete and, in fact, probably ineffective for our purposes. In future studies, the post-exposure equilibration procedure should be extended to determine the time period necessary to obtain a constant weight. Other comparisons have indicated that TSP results from colocated samplers, where equilibration techniques were similar, were not significantly different,⁶ as determined using the same statistical testing.

The levels measured in Winnipeg are very low and consistently near a level which could be ascribed background status. The concentrations found in Winnipeg, compared to other cities show air quality impact to be minimal. Grimmer² lists benzo[a]pyrene concentrations in many urban atmospheres. Sampling in various European cities between 1956 and 1970 yielded results where B[a]P concentrations in heavily industrialized cities were well above our detection limits. Some cities had levels greater than 2 times our limit or concentrations in excess of 50 ng/m³. Highest levels were almost always found in winter. The following are some selected examples.

1) Liege, Belgium	110 ng/m ³ (winter)
2) Prague, Czech.	122 ng/m ³ (winter)
3) Salford, G.B.	210 ng/m ³
4) Gateshead, G.B.	62 ng/m ³
5) Belfast, Ulster	51 ng/m ³
6) Bologna, Italy	212 ng/m ³ (winter)
7) Milan, Italy	610 ng/m ³ (winter)
8) Madrid, Spain	120 ng/m ³ (winter)
9) Essen, F.G.R.	333 ng/m ³ (winter)

The same reference reports on sampling conducted in 21 Ontario cities in 1961-62. In every case neither summer nor winter concentrations were found at a level above our lower detection limit for B[a]P.

References

1. Bennett, M., 1984. Preliminary Survey of Ambient Air Levels of PAH in Winnipeg, Department of Environment and Workplace Safety and Health, Air Standards and Studies Section, Report No. 84-3. pp. 22.
2. Grimmer, G. 1983. Environmental Carcinogens: Polycyclic Aromatic Hydrocarbons. ed. G. Grimmer. CRC Press, publishers.
3. Yamasaki, H., K. Kuwata and H. Mujamoto, 1982. Effects of ambient temperature on aspects of airborne polycyclic aromatic hydrocarbons. Environmental Science and Technology, Vol.16, No.4. pp. 189-194.
4. Bjorseth, A. and B. S. Olufsen, 1983. Long-range transport of polycyclic aromatic hydrocarbons. pp. 507-524. Handbook of Polycyclic Aromatic Hydrocarbons, ed. A. Bjorseth, Marcel Dekker Inc., publishers.
5. Bennett, M., 1983. Investigation of total suspended particulate levels, in air, in the vicinity of the St. Boniface Shell Oil refinery, Department of Environment and Workplace Safety and Health, Air Standards and Studies Section, Report No. 83-4. pp. 13.
6. Bennett, M., 1985. Comparison of simultaneous hi-vol sampling at two sites using 2 different sampling (filtering) media. Personal communication to Dave Bezak, Head of Air Standards and Studies, Manitoba Department of Environment and Workplace Safety and Health. June 17, 1985.